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THE EFFECT OF TAPIOCA-STARCH EDIBLE COATING ON QUALITY OF FRESH-CUT CAULIFLOWER DURING STORAGE

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Abstract
The purpose of this study is to determine preventing browning of cut surface of fresh-cut cauliflower using edible coating. Three different contrentration of tapioca-starch solution (5, 10 and 20 g/L) was used, and gelatine was added at the stable concentration (2.5 g/L). The fresh-cut cauliflower stalk was dipped these solutions for 5 minutes, then dried, packaged and stored at 4°C and 85-90% RH for 28 days. Poliphenol oxydase (PPO) activity, total soluble solids (TSS), color *L*a*b**, and h° values, weight loss, and browning rate were determined seven days intervals during storage. According to the results; PPO activity of edible coated samples were found to be higher than control. Also, hue angle values of coated samples were lower than control group. However, weight losses and browning rate of samples treated with 2,0% of tapioca-starch coating were the lowest compared to the other treatments. Also, TSS of fresh-cut cauliflower stalks coated with tapioca-starch at all doses were determined higher than control group. In conclusion, the edible coating with tapioca-starch was not effect to prevent browning. But this coating increased TSS of samples and decreased weight loss.

Keywords: *Brassica oleraceae* L. var. botrytis, starch-based coating, browning, minimally processed.

Introduction

The consumption of fresh-cut vegetables has been increasing in recent years due to their health benefits. Fresh-cut fruits and vegetables represent a rapidly growing segment of the produce industry as more consumers demand fresh, convenient, and nutritious foods. This is due to the lifestyles of modern consumers that prefer a fresh product that is easier and faster to eat, and desire natural products that can promote health benefits. Quality of fresh-cut fruit products determines their value to consumers and is a combination of attributes, properties, or characteristics including appearance, texture, flavor, and nutritional value. A major challenge faced by the produce industry is to manipulate the quality of fresh-cut produce that the shelf-life is long enough to ensure efficient marketing. Fresh-cut produce deteriorates faster than intact produce because of internal and external browning of the cut surfaces (Gonzalez-Aguilar et al. 2005). One of the latest alternatives to reduce the deleterious effect brought by minimal processing is the application of edible coatings. Acting as a barrier to gases, they are expected to generate a sort of modified atmosphere in each coated fruit piece, and along with relative humidity and optimum refrigeration temperature, they contribute to achieve a reasonable shelf-life in fresh-cut products (Rojas-Grau et al. 2008) The semipermeable barrier provided by edible coatings is aimed to extend the shelf-life by reducing the transfer of moisture, aroma and flavor compounds, gas exchange, respiration and oxidative reaction rates, as well as suppress physiological disorders on fresh-cut fruits (Baldwin et al. 1996, Park, 1999, Wong et al. 1994). In addition, edible coatings can be used as carriers of active compounds, such as antimicrobial agents, which can be used to decrease the population of spoilage and pathogenic microorganisms (Glass and Johnson 2004). One major advantage of using edible coatings is that several active ingredients can be incorporated into the polymer matrix and consumed with the food. Traditionally, edible coatings have been used in the fresh-cut industry as a strategy to reduce the undesired effects that minimal processing produces on intact fruit tissues (Giacalone et al. 2010). Polysaccharides generally present a good barrier to oxygen at low relative humidity (RH) due to their tightly packed structure and low solubility. Polysaccharide-based coatings have been used to extend the shelf-life of fresh-cut fruits and vegetables by reducing respiration rate and gas exchange due to selective permeabilities to O_2 and CO_2 (Rojas-Grau et al. 2009). One shortcoming of polysaccharides is they provide poor moisture barrier due to their hydrophilic character. Chitosan, starch, cellulose, alginate, carrageenan, gelatin, zein, gluten, whey, carnauba, beeswax and fatty acids are the most commonly used compounds to form edible coatings (Baldwin et al. 2011, de Aquino et al. 2015, Shit and Shah 2014). Polysaccharide-based edible coatings may include cellulose derivatives; starch and its derivatives, alginate, pectin, and gellan gum (Olivas and Barbosa-Canovas 2005, Valencia-Chamorrosa et al. 2011). Starch based films have been particularly considered for the reason that they exhibit physical characteristics similar to synthetic polymers: transparent, odorless, tasteless, semi-permeable to CO_2 and resistant to O_2 passage (Nisperos-Carried, 1994). Tapioca starch, naturally or modified, is increasing its utility in food industry because it has some inherent properties that are demanded. The purpose of this study is to determine the effect of tapioca starch-based edible coating on some biochemical characteristics of fresh-cut cauliflower stalks.

Material and methods

Plant Material

Cauliflower (*Brassica oleraceae* L. var. botrytis) were obtained from Kocaeli Wholesale Distribution Center and immediately brought to the laboratory. The cauliflower were screened for uniformity such as being free from any mechanical damages and diseases, and also for similar stage of maturity. The cauliflower separated into stalks. This stalks was used to investigate coating.

Preparation of tapioca starch-based edible coating

For this purpose tapioca starch which is extracted from cassava root (*Manihot esculenta*) was used as polysaccharide material. The tapioca starch-based (TS)-solution at the doses of 5 g/L, 10 g/L and 20 g/L was prepared. Since TS did not form gel at the low temperature, solution was heated until $65^{o}C$ temperature. For providing flexibility of coating, gelatin was added into all starch-solutions at the 2.5 g/L doses. After solution prepared, the cauliflower stalks dipped into solution at the 40^{o} temperature for 3 min. Then all samples were dried at room temperature for fifteen minutes.

Packaging and Storage Conditions

200 g of fresh-cut cauliflower stalks of each replicate was placed in a plastic box (polyethylene terephthalate (PET)) with cover and 110x110x50 mm in size. All treated samples were stored in a cold room at 5 ±1°C and a relative humidity of 85-90% for 28 days.

Color measurements

Color measurements (L*, a*, and b* values) were performed using a chromometer CR-400 (Konica Minolta, Inc. Osaka, Japan) equipped with illuminant D65 and 8 mm aperture of the instrument for illumination and measurement. The instrument was calibrated with a white reference tile (L* = 97.52, a* = −5.06, b* = 3.57) prior to measurements. The L* (0 = black, 100 = white), a* (+ red, − green), and b* (+ yellow, − blue) color coordinates were determined according to the CIELab coordinate color space system (Radzeviciu et al. 2014). Hue angle (ho = tan-1 (b*/a*) when a* > 0 and b* > 0 or ho=180o+ tan-1 (b*/a*) when a*< 0 and b > 0) was calculated from the a* and b* values (Lancester et al. 1997). Color measurement was done three different point of each stalks of each replicate.

Polyphenol oxidase activity (PPO)

To measure polyphenol oxidase activity, 5 g of homogenized fresh-cut cauliflower stalk was extracted with 0.1 M phosphate buffer, pH 7 containing 5 g of polyvinylpyrrolidone using magnetic stirrer for 15 min. The homogenate was filtered through Whatman No. 1 filter paper, and the filtrate collected as an enzyme extract. PPO activity was determined by a spectrophotometric method based on an initial rate of increase in absorbance at 410 nm (Soliva et al. 2000). Phosphate buffer pH 7 (0.1 M, 1.95 mL), 1 mL of 0.1 M catechol (substrate) and 50 µL of the enzyme extract were pipetted into a test tube and mixed thoroughly. The mixture was rapidly transferred to a cuvete of path lenght 1-cm. The absorbance at 410 nm was recorded continuously at 25°C for 5 min using ultraviolet-visible (UV-VIS) spectrophotometer (UV Mini 1240, UV-VIS Spectrophotometer, Shimadzu, Japan) (Arnnok et al. 2010)

Browning Rate (%)
In each analysis period, the number of the browning samples is to rate to the total number of the samples in the box, and calculated as a percentage (%).

Total soluble solids (TSS)
TSS were determined for each sample fruit in three replications using an Atago DR-A1digital refractometer (Atago Co. Ld., Japan) at 20 °C and expressed as percent value (%) (Kasım and Kasım 2015)

Weight losses
Weight of each sample with three replication of each treatment group was recorded on the day of harvest and on the sampling dates. Cumulative weight losses were expressed as percentage loss of original weight.

Statistical analysis
Experiments were conducted in acompletely randomized design with a minimum of-three replications per storage treatments per sampling date. Data were analyzed by ANOVA and differences among means were determined by the Duncan's multiple range test with significance level at $p<0.05$.

Results and discussion
Total Soluble Solids (TSS)

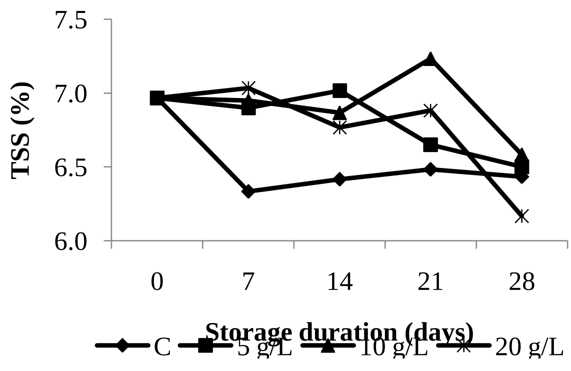

Figure 1. The TSS (%) values of cauliflower stalks that fresh-cut and coated with tapioca starch at different doses. C: control

TSS values of samples in all treatment groups were shown in Fig. 1. As shown Fig. 1, while TSS of control group decreased, tapioca starch-based coating significantly ($p<0.05$) increased TSS of samples in all doses. But, among the treatments there was no seen evident changes. In previously study, harton plantain (*Musa paradisiaca*) was coated with cassava starch-based coating material, but the authors did not found significant difference with a confidence level of 95% in the concentration of total soluble solids (TSS) (Cardozo et al. 2015). The result of the present study is inappropriate with this result, but we used the fresh-cut samples, however, the authors used intact banana fruits. So, the cauliflower stalks could be metabolized the coating material, therefore it can be said that the TSS of the samples found to be high. When banana is considered, since the fruit bark peeled so the coating material did not effect on the TSS value of banana.

Polyphenol oxydase (PPO) Enzyme Activity

Browning due to oxidation of phenols, which is often catalyzed by the polyphenol oxidase enzyme to form colored melanins, decreases the nutrient content in fruits (Vamos-Vigyazo, 1981). The PPO enzyme activity of fresh-cut and coated with TS, was higher than control group, in all doses of coatings (Fig. 2).

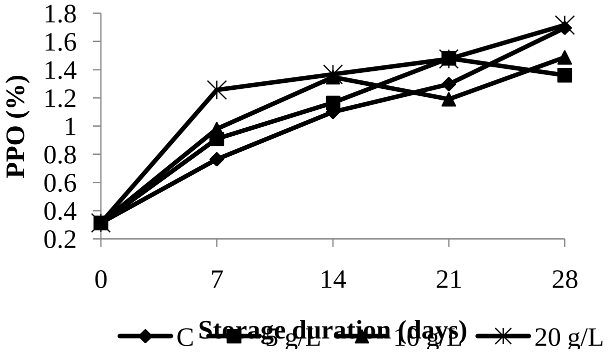

Figure 2. The PPO (%) values of cauliflower stalks that fresh-cut and coated with tapioca starch at different doses. C: control

The highest PPO values were obtained by the coating treatment 20 g/L, and also the differences between this treatment and the other coatings and control group were significant, statistically ($p<0.05$). The PPO enzyme activity of cauliflower stalks fresh-cut and coated with TS, was higher than control group, in all doses of coatings. Therefore, it can be said that the starch-based coating material caused the increase of PPO. This reason is due to the starch metabolize by the samples, and cutting of the samples caused increase the respiration rate so that the other secondary metabolizm rate is increase. Combination of citric acid dipping (5 g/L) and cassava starch coating (10 g/L), with and without glycerol (10 g/L), delayed carotenoid formation and browning reactions of fresh-cut mango during storage was found by Chiumarelli et al. 2010. Similarly, de Moura et al. (2016) concluded that, the lowest PPO activity of mangaba fruit (*Hancornia speciosa*) was found in the pulp of fruit coated with the highest starch concentration tested (4%). But in the present study is not agree with this findings.

Browning Rate

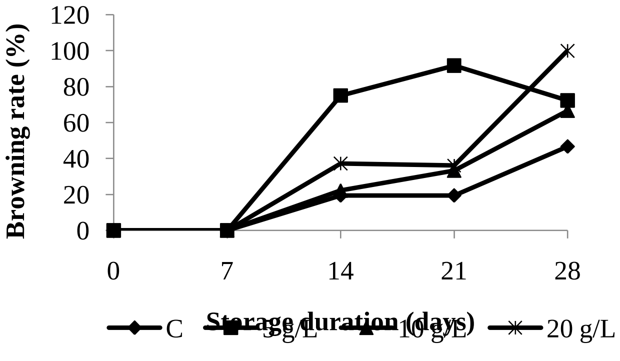

Figure 3. The browning rate (%) values of cauliflower stalks that fresh-cut and coated with tapioca starch at different doses. C: control

Fruits are living tissues that undergo enzymatic browning, texture decay, microbial contamination and undesirable volatile production, highly reducing their shelf-life, if they are in any way wounded

(Tapia et al. 2008). Although, the PPO activity of samples coated with 20 g/L TS was high, the browning rate of cauliflower coated with the 5 g/L TS was found higher than the other coating treatments and control (Fig. 3). However, the differences between these two treatment was not significant at the level of $p<0.05$. But the differences between 5 g/L TS treatment and 10 g/L TS and control is significant. Therefore, it could be concluded that the coating treatments were not effect on browning rate of samples.

L values*

*L** values of samples showed a decreasing trend for the first 7 days of storage, but after that time it started to increase, and they showed sharp increase especially the samples treated with 10 g/L and 20 g/L TS at the day of 21. Also differences among the storage time was significant statistically ($p<0.05$). Furthermore, the differences between samples treated wit 5 g/L TS and the other treatment groups were found to be significant.

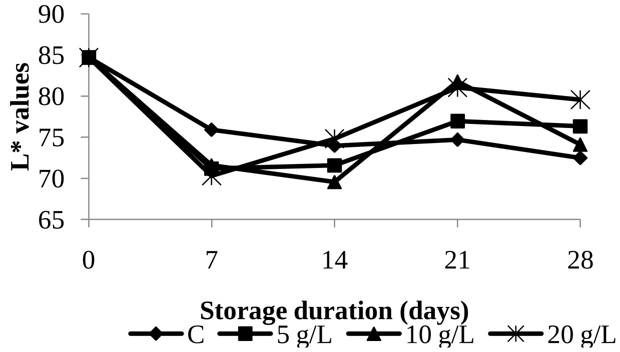

Figure 4. The *L** values of cauliflower stalks that fresh-cut and coated with tapioca starch at different doses. C: control

In a study, it was found that the alginate coatings of fresh cut nectarine were effective on delaying the evolution of the parameters related to postharvest ripening, such as color (Hue, L*) and loss of acidity (Chiabrando and Giacalone 2013). In the present study, coatings of fresh-cut cauliflower stalks with 20 g/L TS was effect on luminosity of samples, both 21th day and at the end of storage periods. The samples into this treatment were stayed brighter than the other treatments.

h^o values

Color, flavor, texture, and nutritive value are generally recognized as the four quality factors of fruits and vegetables. The natural pigments, chlorophylls, carotenoids, and anthocyanins, form the chemical basis of color. Enzymatic and non-enzymatic browning contributes to coloring of certain processed fruits and vegetables (Jen, 1989). The *h^o* values of fresh-cut cauliflower stalks treated with tapioca starch with different doses were given in Fig. 5. According to the Fig. 5, the *h^o* values of samples in all treatment groups decreased during the storage. But this decrease was found the lowest in control group, and followed bay 10 g/L TS, 20 g/L TS and 5 g/L TS treatments.

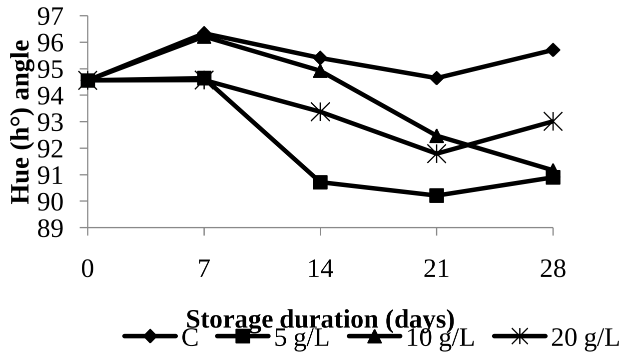

Figure 5. The hue (h^o) angle values of cauliflower stalks that fresh-cut and coated with tapioca starch at different doses. C: control

Also differences among the treatments were found to be significant statistically at the level of $p<0.05$. The h° values of samples treated with 5 g/L TS, was lower than those of the other treatment during storage. H° values is shown true color of samples. Therefore it can be said that, the color of samples treated with tapioca starch was darkened compared to control. Also, browning rate and PPO activity of coated samples is higher than conrol group. Furthermore, it was found in a study that the hue angle of surface color of minimally processed pummelo coated with the two starches did not differ from the control (Kerdchoechuen et al. 2011). So, this result supported to our findings, too.

Weight Losses

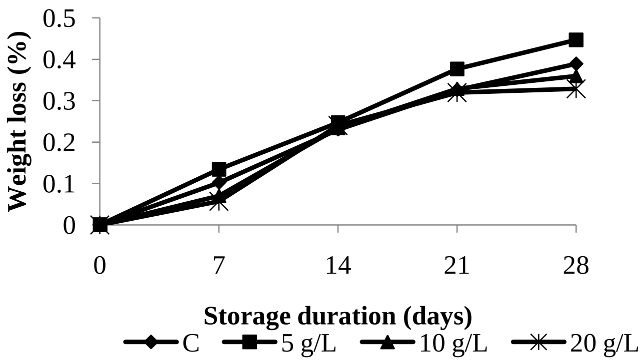

Figure 6. The weight loss (%) values of cauliflower stalks that fresh-cut and coated with tapioca starch at different doses. C: control

Weight loss values of samples in all treatment gruops increased during storage, but tapioca starch based coating reduce weight losses especiall high dose (20 g/L) compared to other treatments, and also differences between this treatment and the other treatments were significant statistically ($p<0.05$). The weight loss during the storage period, implying quality loss, and, consequently, consumer rejection. According to Han and Gennadios, 2005, the edible coatings can protect fruits and vegetables from dehydration due to their moisture barrier property, resulting in an extension of the shelf life of minimally processed products. But, Placido et al., (2015) concluded that, in pequi fruit, the vitamin C, titratable acidity, soluble solids contents and weight loss showed that starch-based coatings did not achieve satisfactory results. Despite these results, it was found in the present study that the tapioca-starch based coatings reduced weight loss in the case of fresh-cut cauliflower.

Conclusions

In the present study it was studied the effect of coating with tapioca starch (TS)-based coating film on some quality characteristic of fresh-cut cauliflower during storage. As findings of research, coatings with TS decreased weight losses especially high dose, and the TSS of fresh-cut caulifower in all coating doses was higher than control. While the coating treatment was not effect darkening of the samples, brightness of samples increased by coatings.

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